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ABSTRACT

The Big Cypress Swamp differs from the adjacent Everglades in topography, soils, water quality, and vegetation. Because the Swamp has relatively more high land, inundation and soil deposition are less extensive in the Swamp than in the Everglades. Soil in the Swamp is usually a thin (less than 0.6 meters) layer of marl, sand, or mixtures of the two, or is absent where limestone crops out, whereas soil in the Everglades is usually deeper organic peat. Vegetation in the Swamp is closely associated with topography, water inundation, and soils, and is more diverse and forested than it is in the Everglades.

INTRODUCTION

The Big Cypress Swamp is a flat, swampy land of about 3,120 square kilometers west of the Everglades (Figure 1). It differs from the Everglades in its relatively higher land elevations, its thinner soils of marl or sand, and its forest vegetation.

The elevation of the Swamp ranges from about 4 to 12 meters above sea level in the north to sea level at the coastal mangrove forest. The land surface is relatively flat except for numerous low mounded limestone outcrops and small circular and elongated depressions. The slope of the land is generally to the south and varies from about 0.08 to 0.16 meters per kilometer (Carter and others, written commun., 1973).

The soil in the Swamp is usually a thin (less than 0.6 meters) layer of marl, sand, or a mixture of the two, or is absent where limestone is at the surface. Muck and peat, however, accumulate to depths of 1 meter or more in depressions in the bedrock (Davis, 1943).

The Swamp is characterized by an abundance of small and stunted cypress trees, and by cypress trees of moderate size associated with depressions in the bedrock. Pine and hammock forests occur on land slightly higher than cypress forest land.

Natural drainage in the Swamp is by slow, overland flow to the south. Well defined streams do not exist except along the southwest coast where the Swamp merges with the estuarine mangrove forest.

Man began to drain the Big Cypress in the 1920's with the construction of the Barron River Canal (Figure 2). Subsequently the Turner River Canal was dug 8 kilometers to the east. Even though these canals have not been effective in lowering water levels, both intercept substantial quantities of water from the Okaloacoochee Slough and divert them directly to the estuaries.

A major drainage system, the Golden Gate Canals, was started in the Big Cypress in the early 1960's. As a result of this system water levels in the western part of the Swamp have been lowered 0.6 meters on the average and seasonal flooding halted.

Land-use and water-management practices can alter water quality. Farming, for example, often introduces pollutants such as excessive nutrients and dissolved solids into surface waters where they can be widely distributed by canal drainage. Intensive farming, however, occurs primarily north of the Big Cypress.

GEOLOGY

Limestone of the Tamiami Formation of late Miocene age, and limestone of the Anastasia Formation and the Pamlico sand of Pleistocene age underlie the Big Cypress. The Tamiami limestone is exposed at the land surface or overlain by a thin veneer of soil. The limestone surface is scalloped by many small depressions and elongated troughs, but lacks the pinnacle rock of the Miami Limestone (Hoffmeister and others, 1967). The Tamiami Formation has a maximum thickness of about 45 meters (Parker and others, 1955).

The Hawthorn Formation, of middle Miocene age, underlies the Tamiami Formation. Although the Hawthorn Formation is composed predominantly of relatively impermeable clay, it also contains lenses of sand and gravel and thin layers of limestone and shell. This formation probably ranges in depth from less than 30 meters near Immokalee to more than 60 meters near Naples (McCoy, 1962).

The Tampa Formation, of early Miocene age, underlies the Hawthorn Formation. Under the Big Cypress it is primarily a sandy limestone with quartz sand or a calcareous sandstone. Near Sunniland the formation is about 60 meters thick and the top is more than 120 meters deep.

Oil was discovered in the Lower Cretaceous sediments in the northern Big Cypress (McCoy, 1962). Florida's first producing oil well was developed in 1943 at Sunniland. This well was 3,488 meters below sea level and had an initial production of 97 barrels of oil per day. Many more oil wells were drilled after 1943, and by 1973, 17 wells at Sunniland were producing about 50,000 barrels of oil per month. A number of exploratory wells were dug in different parts of the Big Cypress in the early 1970's, and oil was found at several.

GROUND WATER

The upper limestone of the Tamiami Formation and Pamlico sand and Anastasia Formation form a shallow aquifer beneath the Big Cypress. The highly permeable limestone is the principal part of the aquifer. Fine sand, clay, and marl in the lower part of the Tamiami Formation and in the upper part of the Hawthorn Formation are relatively impermeable and serve as a base for the shallow aquifer and as a confining unit for the deeper Floridan aquifer (McCoy, 1962).

The shallow aquifer in the Big Cypress extends from the land surface to a depth of 39 meters at its western edge near Naples, to about 18 meters near Sunniland, and wedges out near the eastern edge of the Swamp (Klein and others, 1970). Water in the aquifer is a hard calcium bicarbonate type, and except in coastal areas of saltwater contamination, contains little chloride. The aquifer supplies water to the city of Naples (McCoy, 1962).

The Floridan aquifer occurs beneath the Swamp at depths greater than 120 meters. Its thickness is not known, but several wells 600 meters deep do not completely penetrate it (McCoy, 1962). The Floridan aquifer yields large amounts of water to wells by natural flow. The dissolved solids of the water range from 3,000 to 5,000 mg/l (Klein and others, 1970).

SURFACE WATER

Rainfall in the Big Cypress averages 133 centimeters per year, but has ranged from 88 to 200 centimeters per year (Klein and others, 1970). Nearly 80 percent of the rain falls during May through October.

The Big Cypress Swamp is part of a larger drainage area, covering almost 6,400 square kilometers, which includes the tidal forest, marshes, and bays, as well as the Swamp itself (Figure 1). Based on drainage patterns this area is divided into three subareas (Figure 2). Subarea A, about 1,170 square kilometers in the northeastern part of the Big Cypress, drains southeastward into Conservation Area 3A; some of this water eventually enters Everglades National Park. Subarea B, about 1,430 square kilometers in the western part, has an extensive system of canals that drain southward into the Gulf of Mexico. Subarea C, about 3,760 square kilometers in the central part of the Big Cypress, drains southward toward the western part of Everglades National Park. The Park receives each year an average of 0.67 cubic kilometers (541,500 acre-feet) of water from subarea C or 56 percent of the total received by the Park from outside sources other than rainfall (Klein and others, 1970).

In the Big Cypress, water accumulates in depressions, such as sloughs, marshes, and strands, and flows slowly toward the estuaries. The Fakahatchee Strand and the Okaloacoochee Slough are the largest and most conspicuous water pathways in the Swamp (Figure 2). Historically, water flowed southward in the Okaloacoochee Slough and into the Fakahatchee, but today a system of highway borrow canals and the Barron River and Turner River canals effectively cut off and divert the overland flow from the Okaloacoochee Slough directly to the estuaries.

Corkscrew Marsh and Swamp is a major drainage unit at the north end of the Big Cypress (Figure 2). Because its direction of drainage is west toward the Gulf of Mexico, it is not included within the drainage area.

The quality of water in the remote, undrained parts of the Big Cypress is generally good, and probably best reflects South Florida's pristine water-quality conditions. The Everglades, on the other hand, has been affected more than the Big Cypress by land-use and water-management practices, and water quality, particularly in the northern part of the Everglades, is of poorer quality than that in the Swamp.

The concentrations of dissolved solids indicate general water-quality conditions of a fresh-water environment. In the Big Cypress concentrations averaged about 250 mg/l (Klein and others, 1970). In the northern Everglades, for comparison, three long-term stations (1950-1970) averaged 471 to 541 mg/l (McPherson, 1973A). Sources of dissolved solids include soft limestone, agricultural and urban runoff, salty artesian ground water, and sea water. In the northern Everglades dissolved solids are attributable primarily to saline ground water and agricultural runoff, whereas in the Big Cypress they are attributable to soft, exposed limestone. Interestingly, dissolved solids at a long-term station (1950-1965 and 1969) in the southern Everglades averaged 205 mg/l (McPherson, 1973A). The relatively low value probably reflects an environment with little exposed limestone.

Although average long-term concentrations of dissolved solids in the southern Everglades are relatively low, concentrations are increasing. Chlorides, which are indicative of dissolved solids, have increased more than 4 times over the last 12 years at one station in Everglades National Park, whereas they have remained essentially the same at another station in the Big Cypress (Figure 3). The increased concentrations of solids in the southern Everglades reflect increased canal transport of water from the north by L-67 canal. This canal was dug in 1962, and subsequently extended south of U. S. Highway 41.

Concentrations of the micronutrients, nitrogen and phosphorus, are also indicative of water quality.

High concentrations may cause excessive growth of aquatic plants which can degrade water quality by such things as reduction in dissolved oxygen, production of obnoxious odors, and aesthetic impairment. Concentrations of these elements in the surface waters of the Big Cypress are usually low, averaging 0.03 mg/l and 0.10 mg/l N (Klein and others, 1970). For comparison, average concentrations in water of urban canals of South Florida are 6 to 15 times greater (Klein and others, written commun., 1973).

Although water in the Big Cypress is relatively good, it has been degraded to some extent by man's activities. Canals in subarea B and in the western part of subarea C transport potentially toxic metals to the estuaries in concentrations and amounts greater than those transported by overland flow (Little and others, 1970). Magnesium, iron, cobalt, cadmium, copper, and zinc have been concentrated above natural levels in Chokoloskee Bay presumably because of transport down Turner River Canal from agricultural land to the north (Harris and others, written commun., 1973). Pesticides are low in concentration in surface water of the Big Cypress but are concentrated in soils and biota (Klein and others, 1970). Although chloride tends to be in low concentration (averaging about 20 mg/l) in the interior parts of the Big Cypress, high concentrations (as much as 5,350 mg/l) have been detected around several exploratory oil-well sites (Wimberly, written commun., 1973).

VEGETATION

The fresh-water vegetation of the Big Cypress is divided into six associations: PINE FORESTS, CYPRESS FORESTS, MIXED SWAMP FORESTS, PRAIRIES, and MARSHES (McPherson, 1973B). Each association is related to important factors such as fire, water depth, and period of inundation.

PINE FORESTS are open areas of pine (*Pinus elliottii*), cabbage palm (*Sabal palmetto*), saw palmetto (*Serenoa repens*), and scattered hardwood shrubs and trees (scientific names are from Long and Lakela, 1971). Grasses are usually the dominant ground cover with common genera such as beardgrass (*Andropogon*), three-awn grass (*Aristida*), and panic-grass (*Panicum*). Sedges, rushes, and composites may also be present in the ground cover. The land is usually a decimeter to several decimeters above the surrounding cypress land. Pine forest is a sub-climax association maintained by fire, which restricts the spread and reduces the density of hardwood trees.

HAMMOCK FORESTS are areas of vegetation including hardwood trees, palms, shrubs, ferns, and epiphytes. They grow on land slightly higher than that of surrounding marshes, prairies, or cypress forest and often stand out on the horizon as a "tree island". Hammock forests often represent a climax community developed in the absence of fire. Areas surrounded by deep water or areas of dense vegetation that retain high humidity and soil moisture are protected from fire. In the northern part of Big Cypress, temperate-zone trees, such as red maple (*Acer rubrum*) and laurel oak (*Quercus laurifolia*) predominate in lower areas and live oak (*Q. virginiana*) and cabbage palm predominate in higher areas. To the south, broad-leaved tropical trees and shrubs, such as strangler fig (*Ficus aurea*), wild tamarind (*Lysiloma latisiliqua*), pigeon wood (*Coccoloba diversifolia*), gumbo limbo (*Bursera simaruba*), poison wood (*Metopium toxiferum*), red bay (*Persea borbonia*), and coco plum (*Chrysobalanus icaco*) become dominant, where they grow on numerous small tree islands. These islands are most abundant southeast of a line that extends from the Training and Transition Airport southwestward to Lostmans River. Near the coast, red mangrove (*Rhizophora mangle*) and cabbage palm are generally abundant.

CYPRESS FORESTS are open areas of small cypress trees (*Taxodium*) and a scattered sparse growth of herbaceous plants, such as sawgrass (*Cladium jamaicensis*) or beak rushes (*Rhynchospora*), growing on a thin layer of marl soil or sand over limestone. Cypress domes and strands of larger trees grow over much of the forest. Domes are circular or egg-shaped features that are dome-shaped in profile on the horizon (Figure 4). Strands are elongate areas of large trees that follow drainage depressions. Shrubs and small swamp trees, such as wax myrtle (*Myrica cerifera*), coco plum, and pond apple (*Annona glabra*), are common understory species within the domes and strands.

Cypress domes occur where bedrock surfaces are low (Figure 5). The largest trees are near the center of the dome where bedrock is lowest and organic soils and water deepest. Trees decrease in size toward the periphery of the dome where bedrock is shallow and soils are thin or absent. Vernon (1947) felt that the larger trees were older and that domes were explained by a gradual rise in water related to sea level rise which allowed cypress to spread progressively out from the center of the dome. According to Craighead (1971), however, the change in tree size probably reflects growth rate rather than age, with trees in deeper nutrient-rich organic soil growing faster than those on thin, infertile soil.

The cause of the depressions in the bedrock at the cypress domes is unclear. Large trees could accelerate rock dissolution, but the occurrence of these depressions in widely separate areas supporting different vegetation indicates that other erosional factors are involved (Craighead, 1964). Sink holes and basins are common in Florida and result from the activities of ground water supplemented with surface water erosion (Davis, 1946).

Cypress strands are associated with elongate depressions in the bedrock. Large cypress trees were present in the strands in the early 1900's, but logging has since removed most of them. However, one major area of large virgin cypress remains at Corkscrew Swamp where the National Audubon Society maintains a sanctuary (Figure 6). Some trees there tower 40 meters and have a girth of 8 meters.

MIXED SWAMP FORESTS are areas of dense stands of trees, shrubs, vines, ferns, and epiphytes that usually occur as elongated strands that follow low drainage areas. Elevation of land within a forest is variable and ranges from deep-water areas that are inundated during most of the year to higher areas that are seldom inundated. Most of the land is seasonally flooded for months. The forest is usually a mixture of many shrub and tree species. Cabbage palm, red maple, wax myrtle, coco plum, sweet bay (*Magnolia virginiana*), and red bay are widely distributed. Cypress, willow (*Salix caroliniana*), pop ash (*Fraxinus caroliniana*), and pond apple tend to be more common in deeper water. Hammock vegetation, such as laurel oak, dahoon (*Ilex cassine*), wild coffee (*Psychotria undata*), myrsine (*Myrsine guianensis*), and occasionally live oak and pine grow on the higher land. Although the forest is generally a mixture of many trees, one species, such as willows, may predominate in small burned areas, or pop ash, pond apple, or cypress may predominate in deep water. Cabbage palm predominates at the seaward end of some strands. Large cypress trees dominated much of the forest before logging, but virtually all large trees have been removed.

The Fakahatchee Strand (Figure 2) is the largest mixed swamp forest in the Big Cypress. The Strand was logged in the late 1940's and early 1950's and virtually all the large cypress trees removed. Maple, oak, willow, and other swamp hardwoods became dominant after the cypress removal (Alexander and Crook, written commun., 1973). Despite logging operations and severe fires, the Strand is known for its rich and diverse flora which includes at least 39 species of orchids, some of which are found no where else (Luer, 1964), 20 species of ferns, and 11 species of bromeliads (Finn, 1966). Numerous small lakes are distributed along the central axis of the Strand (Figure 7).

PRAIRIES of the Big Cypress are associations of mixed grasses, sedges, and other herbaceous plants with few trees. They may be seasonally inundated for months (wet prairies), seldom inundated (dry prairies) or intermediate between the two types, depending on land elevation. Common species in wet prairies include maidencane (*Panicum hemitomon*), blackhead rush (*Schoenus nigricans*), star dichromena (*Dichromena colorata*), muhly (*Muhlenbergia capillaris*), water dropwort (*Oxypolis filiformis*), ribbon lily (*Crinum americanum*), hempvine (*Mikania batatifolia*), the low shrub stillingia (*Stillingia sp.*), and scattered marsh vegetation, particularly sawgrass. Common species in dry prairies include saw palmetto and some of the grasses and sedges found in the pine forest. Wet prairies cover large areas south of U. S. Highway 41, where they merge in places almost imperceptibly with marshes. Dry prairies are more common in the northern part of the Big Cypress. Some prairies, particularly those west of State Road 29, have been farmed.

MARSHES are dominated by such forms as cattail (*Typha sp.*), dense sawgrass, arrowhead (*Sagittaria lancifolia*), pickerelweed (*Pontederia lanceolata*), fire flag (*Thalia geniculata*), water rush (*Rhyncospora inundata*), spike rush (*Eleocharis cellulosa*), and bladderwort (*Utricularia sp.*). Vegetation may be dense or sparse. Water is usually several inches deeper than in the surrounding prairies.

Disruption of the native vegetation of the Big Cypress has resulted primarily from logging, farming, and severe fires. Logging began on a small scale in the early 1900's, primarily near coastal settlements, became more extensive after 1920, when rail transportation became available, and reached its peak in the mid-1900's. "Tramways", relict from logging operations, are still detectible on the ground and on aerial photographs. Tramways are elongate and elevated mounds on which railroad track was laid to haul the trees. Although the track was later removed, the mounds remain and are densely covered with hammock vegetation.

Fire, a natural occurrence in the Big Cypress as it is in the Everglades, has increased in severity and frequency through some of man's activities. Hunting and logging bring men with matches and machines. Even though efficient fire-fighting tends to eliminate some catastrophic fires, drainage and the consequent shortening of inundation periods, inevitably increase both the time available for and the susceptibility to burning in much of the Big Cypress.

Farmers often remove native vegetation for crops and pasture. Farming is active at the northern boundary of the Big Cypress, and was more widespread in the Swamp before 1940. Extensive areas of abandoned farm land lie along both sides of State Road 29, and smaller areas lie south of U. S. 41. Recovery vegetation, that differs from the original vegetation, often recolonizes abandoned farm land making recovery to the previous condition uncertain (Alexander and Crook, written commun., 1973). A particular threat to native species are the exotics. Brazilian pepper (*Schinus terebinthifolius*), Australian pine (*Casuarina sp.*) and Cajeput (*Melaleuca quinquenervia*) are all invading old farm land (Alexander and Crook, written commun., 1973).

Numerous agricultural canals and ditches have been dug in the northern part of the Big Cypress; these have lowered the water table (Figure 8), shortened hydroperiods and led to vegetation changes at Corkscrew Swamp (Alexander and Crook, written commun., 1973). Attempts are being made at the Corkscrew Swamp Sanctuary to sustain inundated areas by using dams and by pumping from wells.

ANIMALS

The animals of the Big Cypress are aquatic or water tolerant and are adapted to seasonal inundation. Small animals such as many insect species spend part of their life cycle in water; others such as fishes and prawns are completely aquatic. Many larger animals such as frogs, alligators, some snakes, wading birds and some mammals are dependent on the aquatic environment for food or living conditions. Other species such as deer, bear, or panther, thrive in swamps or dry lands.

Seasonal water fluctuations provide the conditions necessary to feed the animals of the Big Cypress (Kushlan, 1972). During high water, aquatic plant and animal production abounds in the marshes, sloughs, and prairies, and energy stored by the plants is used by small crustaceans, insects and fish. Receding water levels during the dry season force the small aquatic animals to concentrate in scattered ponds, tributary creeks, and sloughs. The concentrated biomass becomes a rich source of food for larger animals. A lowered water level allows wading birds to feed in the remaining water. The wood ibis, for example, feeds on small fish by wading and groping with its bill. The efficiency of its feeding depends directly on the number of food items per volume of water. In South Florida the wood ibis can obtain enough food for breeding only in winter, when the density of small fish becomes high as a result of declining water levels (Kahl, 1962). Two-thirds of the wood ibis of the United States breed in the Big Cypress and are dependent on the seasonally fluctuating water levels there (Leopold and others, 1969).

Most other large animals of the Big Cypress derive some food from the aquatic food web. The water-dependent birds, including rare and endangered species, such as the roseate spoonbill, the Florida Everglades kite, and the southern bald eagle, inhabit the Big Cypress. Other birds and some mammals, such as the Florida panther and the black bear, are not as water-dependent, but they exist in the Big Cypress primarily because it is a wilderness. The wilderness, although now reduced in size, remains because the aquatic nature of the environment has made development difficult.

ECOSYSTEM DYNAMICS

The Environmental Protection Agency (EPA), using models of ecosystem dynamics, compared the functioning of an undrained part of the Big Cypress, the Fakahatchee Strand and its surrounding prairies, with a drained part to the west of the Strand. Total biomass production in the Fakahatchee was twice that in the drained Strand, and woody growth four times greater, indicating that the availability of water controls the facility with which the swamp forest ecosystem can convert sunlight to organic energy. Leaf litterfall was 45 percent greater in the drained strand than in the Fakahatchee, suggesting that the swamp forest system responds to the moisture stress of drainage by thinning of canopy density. Thinning of the canopy would decrease productivity, and would permit more sunlight to reach the forest floor. Increased sunlight in the forest floor would accelerate drying of litter and make the system more vulnerable to fire damage (Carter and others, written commun., 1973).

Cycling of mineral nutrients on the forest floor is also controlled by moisture conditions. Moist conditions accelerate litter remineralization by at least a factor of 1.3 and create favorable conditions for macrodecomposers that further accelerate the process by 1.6 times (Carter and others, written commun., 1973). As a result, concentrations of mineral nutrients increased more rapidly in the litter of the Fakahatchee than in the drained strand.

Biomass production in the wet prairies also is greater by at least 40 percent in the flooded system than in the drained one (Carter and others, written commun., 1973). The removal of ponded waters eliminates periphyton production altogether, which through suppression of forage fish populations, may eventually severely depress the remaining wading bird populations dependent upon the fish resource.

SUMMARY

The Big Cypress Swamp is a flat, swampy area of about 3,120 square kilometers in southwest Florida. It is seasonally inundated over as much as 90 percent of its area. Water moves slowly to the south by overland flow toward the estuaries. Fifty-six percent of the surface water that flows into Everglades National Park comes from the Big Cypress (Subarea C). A substantial amount of water also enters Conservation Area 3 from the Swamp (Subarea A). The western part of the Swamp (Subarea B) is drained by canals and no longer floods extensively.

A shallow aquifer in the Big Cypress extends from the land surface to a depth of 39 meters at its western edge near Naples, to about 18 meters near Sunniland, and wedges out near the eastern edge of the Swamp. Water in the aquifer is a hard calcium bicarbonate type containing low concentrations of chloride, with the exception of coastal areas of salt-water contamination.

The topography of the Swamp is relatively flat, except for numerous mounded low limestone outcrops and small circular and elongate depressions. Land elevation, at the same latitude, is generally higher in the Swamp than in the Everglades.

Although muck and peat soils occur in the depressions in the bedrock, soil in most of the Swamp is a thin (less than 0.6 meters) layer of marl, sand, or a mixture of the two.

The quality of water in the Big Cypress, particularly in the undrained parts, is, in general, of better quality than the water in the Everglades. Some contamination by metals, pesticides, and other potentially toxic chemicals does occur, however.

The vegetation in the Swamp is related to water depth, period of inundation, fire, and other factors. Water cover, of course, affects fire. Man has altered vegetation in the Swamp through drainage, farming, logging, and the introduction of exotic species.

Animals of the Big Cypress are adapted to and many are dependent on seasonal inundation of the land. Most large animals derive some food from the aquatic food web.

Availability of water affects organic production in the Swamp forest and wet prairie. Drainage reduces production in the forest by half and increases leaf litterfall 45 percent. Drainage in the wet prairie completely suppresses periphyton production.

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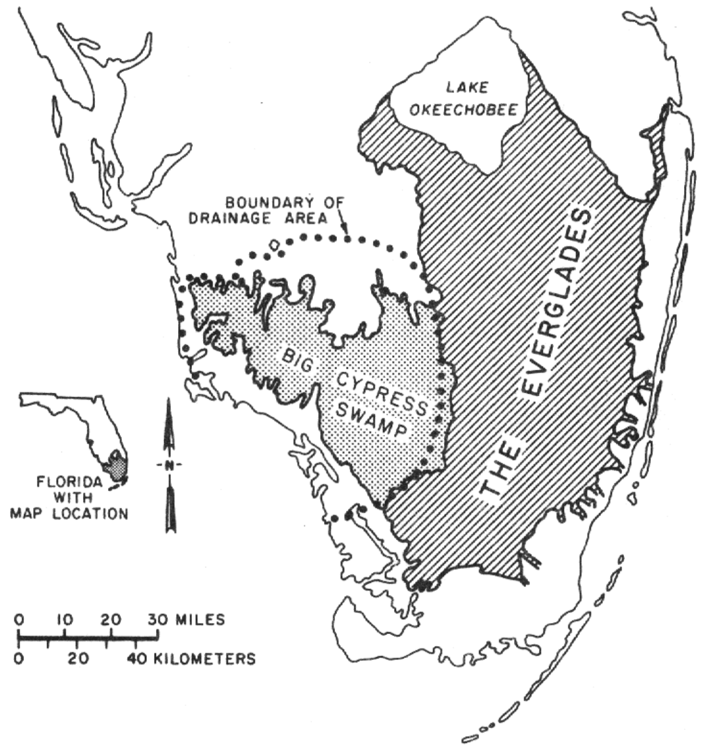

Figure 1. Map of southern Florida showing the Everglades and the Big Cypress Swamp (adapted from Davis, 1943), and the Big Cypress Swamp drainage area (from Klein and others, 1970).

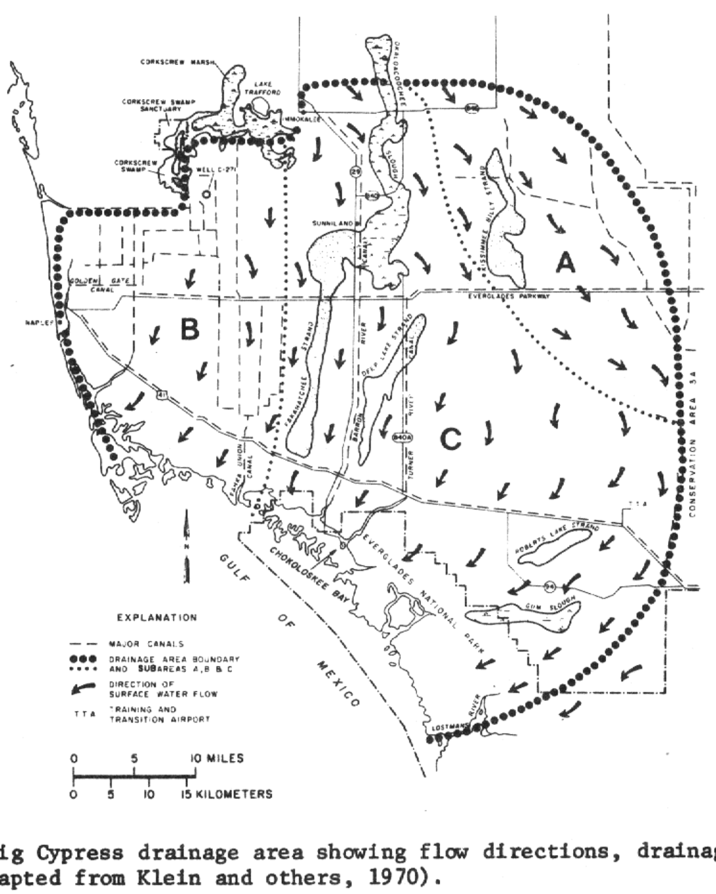

Figure 2. Map of the Big Cypress drainage area showing flow directions, drainage canals, and large strands and sloughs (adapted from Klein and others, 1970).

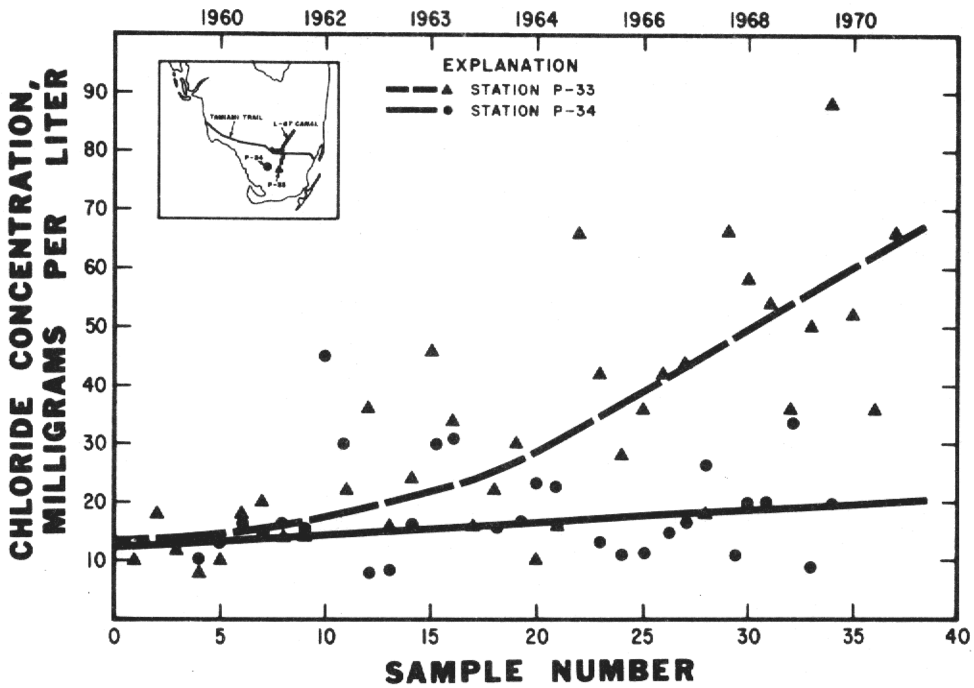

Figure 3. Concentrations of chloride in the waters of the southern Everglades (P-33) and the Big Cypress (P-34) during 1959-1970 (Klein and others, 1974).

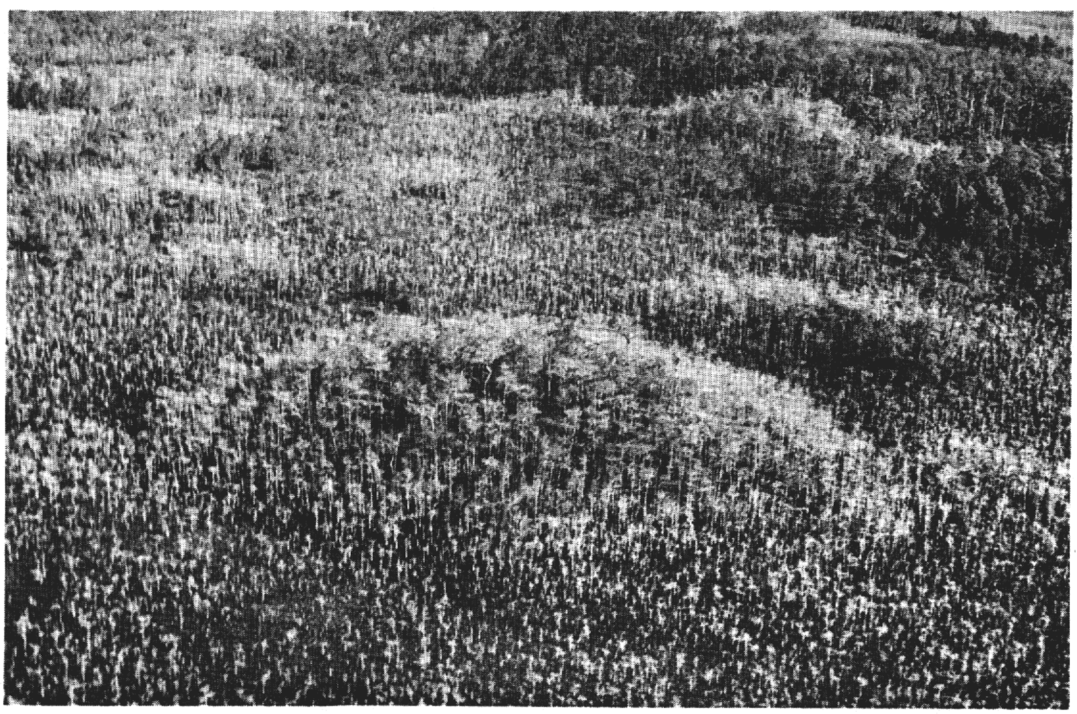

Figure 4. Oblique aerial photography showing cypress domes and pine forest in the Big Cypress.

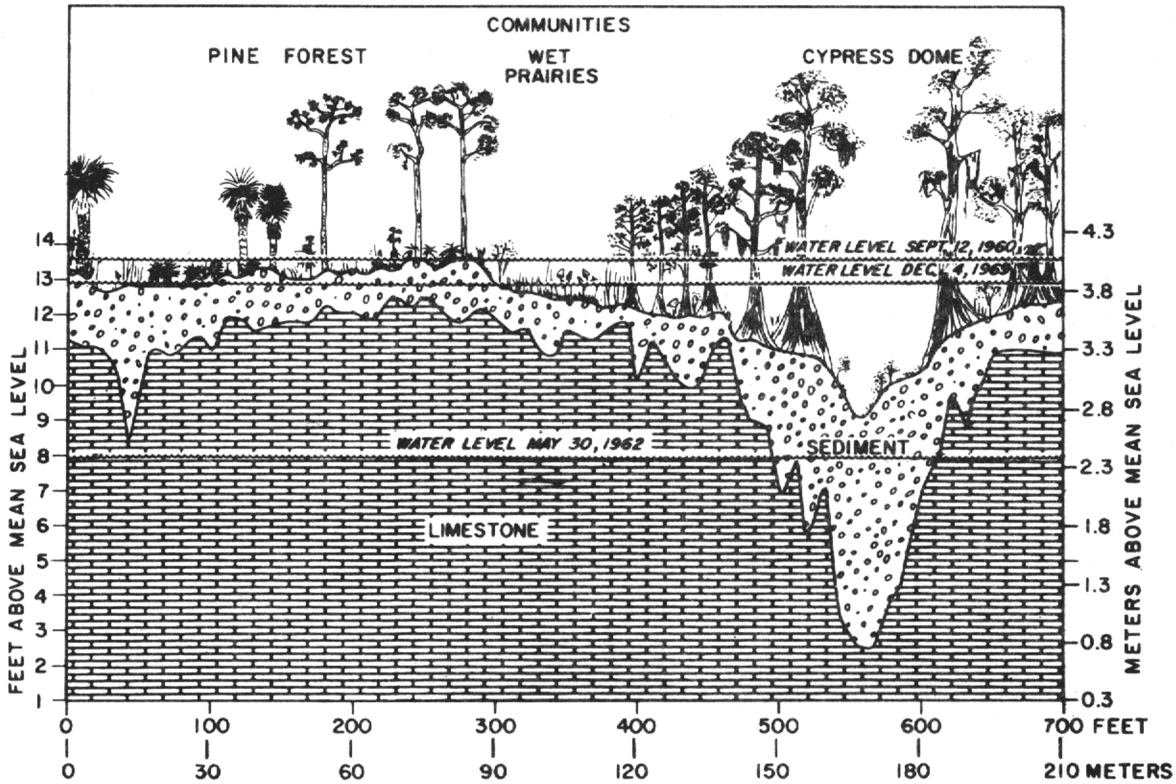

Figure 5. Vegetal transect in the Big Cypress showing the relation of bedrock to plant associations (from Klein and others, 1970).

Figure 6. A shallow pond filled with water lettuce (*Pistia stratiotes*) and surrounded by large cypress trees and a single cabbage palm at Corkscrew Swamp Sanctuary.

Figure 7. One of the numerous small lakes of the Fakahatchee Strand.

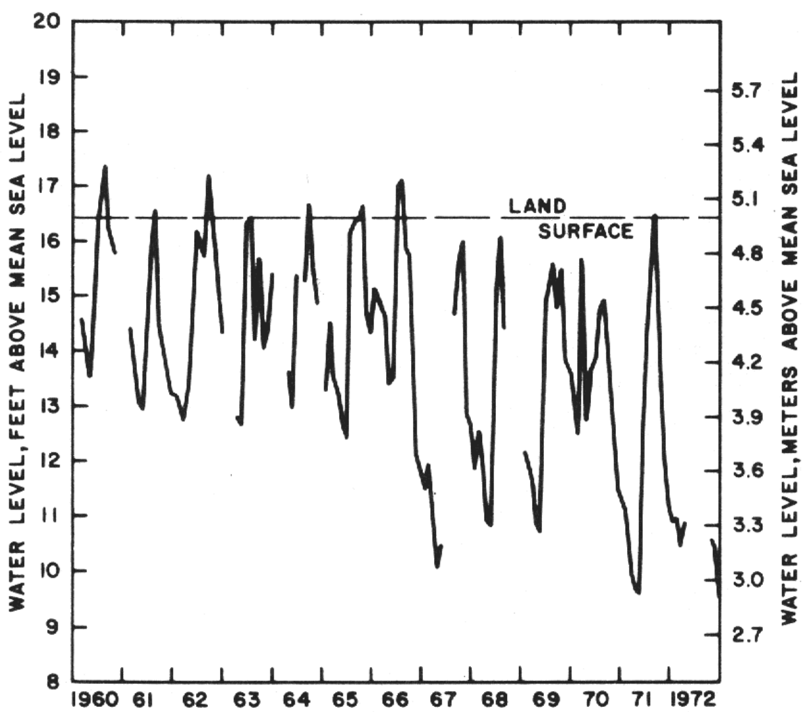

Figure 8. Water level at Well C-271 in the northwestern Big Cypress between 1960-1972. Location of well shown in Figure 2.